

WHAT IS CLAIMED IS:

- 1 1. An apparatus for use on a bottom hole assembly (BHA) for conveying in a
2 borehole in an earth formation, the apparatus comprising:
3 (a) an orientation sensor making measurements indicative of a toolface angle
4 of said BHA during rotation of the BHA;
5 (b) at least one resistivity sensor for making measurements of a resistivity of
6 said earth formation during said continued rotation; and
7 (c) a processor for determining from said resistivity measurements and said
8 orientation sensor measurements a apparent dip angle between an
9 axis of said borehole and an interface in said earth or mation
10 wherein said BHA has a non-uniform rate of rotation.
11
- 1 2. The apparatus of claim 1 wherein said interface is a bed boundary.
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- 1 3. The apparatus of claim 1 wherein said interface is an oil-water contact.
2
- 1 4. The apparatus of claim 1 wherein said at least one resistivity sensor comprises
2 two axially spaced apart resistivity sensors.
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- 1 5. The apparatus of claim 1 wherein the at least one resistivity sensor comprises a
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2 galvanic sensor.

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1 6. The apparatus of claim 5 wherein said galvanic sensor comprises a focused
2 sensor.

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1 7. The apparatus of claim 1 wherein said at least one sensor comprises an induction
2 sensor.

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1 8. The apparatus of claim 7 wherein said induction sensor comprises a sensor having
2 a coil with an axis inclined to an axis of said BHA.

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1 9. The apparatus of claim 1 wherein said resistivity sensor comprises a plurality of
2 transmitter-receiver spacings and further comprises circuitry for measuring at
3 least one of (i) an amplitude difference, and, (ii) a phase difference of signals
4 measured at said plurality of spacings.

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1 10. The apparatus of claim 1 wherein said orientation sensor is associated with a first
2 processor and said at least one resistivity sensor is associated with a second
3 processor, said first and second processors being on a common bus.

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1 11. The apparatus of claim 1 wherein said orientation sensor comprises a
2 magnetometer.

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1 12. The apparatus of claim 1 wherein said orientation sensor comprises an
2 accelerometer.

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1 13. The apparatus of claim 1 further comprising a gyroscope for providing a
2 measurement indicative of an inclination and azimuth of said borehole.

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1 14. The apparatus of claim 1 wherein said processor further determines a bias in said
2 orientation measurements.

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1 15. The apparatus of claim 1 wherein said orientation sensor comprises a pair of
2 magnetometers, and wherein said processor further determines a scale factor
3 relating the outputs of the two magnetometers.

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1 16. The apparatus of claim 1 wherein said resistivity sensor is mounted on one of (i) a
2 pad, (ii) a rib, and, (iii) a stabilizer.

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1 17. The apparatus of claim 1 wherein said processor further corrects an image of said
2 borehole.

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1 18. The apparatus of claim 1 wherein said processor further controls a drilling
2 direction of said borehole based on said apparent dip angle.

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1 19. The apparatus of claim 1 wherein said processor determines said apparent dip
2 angle based on an apparent rate of penetration.

3

1 20. A method of determining a dip characteristic of an earth formation, the method
2 comprising:

3 (a) conveying a bottom hole assembly (BHA) into a borehole in an earth
4 formation;

5 (b) using an orientation sensor on said BHA for making measurements
6 indicative of a toolface angle of said BHA during rotation of the
7 BHA;

8 (c) using at least one resistivity sensor on said BHA for making
9 measurements of a resistivity of said earth formation during said continued
10 rotation; and

11 (d) determining from said resistivity measurements and said
12 orientation sensor measurements said dip characteristic of said earth
13 formation, said determination correcting for a non-uniform rate of
14 rotation of said BHA.

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1 21. The method of claim 20 further comprising using said determined dip
2 characteristic for controlling a drilling direction of said borehole.

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1 22. The method of claim 20 wherein said dip characteristic comprises a apparent dip
2 angle between an axis of said borehole and a bed boundary in said earth
3 formation.

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1 23. The method of claim 20 wherein determining said dip characteristic further
2 comprises using measurements from an additional resistivity sensor spaced apart
3 axially from said at least one resistivity sensor.

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1 24. The method of claim 20 wherein the at least one resistivity sensor comprises a
2 galvanic sensor.

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1 25. The method of claim 24 wherein said galvanic sensor comprises a focused sensor.

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1 26. The method of claim 20 wherein said at least one resistivity sensor comprises an
2 induction sensor.

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1 27. The metod of claim 26 wherein said induction sensor comprises a sensor having
2 a coil with an axis inclined to an axis of said BHA.

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1 28. The method of claim 20 wherein said resistivity sensor comprises a plurality of
2 transmitter-receiver spacings, and using said resistivity sensor further comprises a
3 making measurements of at least one of (i) and amplituded difference, and, (ii) a

4 phase difference of signals measured at said plurality of spacings.

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1 29. The method of claim 20 further comprising coupling a first processor associated
2 with said orientation sensor and a second processor associated with the at least
3 one resistivity sensor to a common bus.

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1 30. The method of claim 20 wherein said orientation sensor comprises a
2 magnetometer.

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1 31. The method of claim 20 wherein said orientation sensor comprises an
2 accelerometer.

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1 32. The method of claim 20 further comprising using a gyroscope for providing a
2 measurement indicative of an inclination and azimuth of said borehole.

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1 33. The method of claim 20 further comprising determining a bias in said
2 orientation measurements.

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1 34. The method of claim 20 wherein said orientation sensor comprises a pair of
2 magnetometers, the method further comprising determining a scale factor
3 relating the outputs of the two magnetometers.

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1 35. The method claim 20 wherein said resistivity sensor is mounted on one of (i) a
2 pad, (ii) a rib, and, (iii) a stabilizer.

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1 36. The method of claim 20 further comprising obtaining an image of said borehole.

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1 37. The method of claim 36 further comprising correcting said image.

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38. The method of claim 36 further comprising identifying tool face angles associated
with a sticking of the BHA.